PDFS of Upper Tropospheric Humidity

Darryn Waugh, Ju-Mee Ryoo, Tak Igusa
Johns Hopkins University

Introduction

Climate is sensitive to upper tropospheric humidity, and it is important to know

- the distributions of water vapor in this region, and
- the processes that determine these distributions.

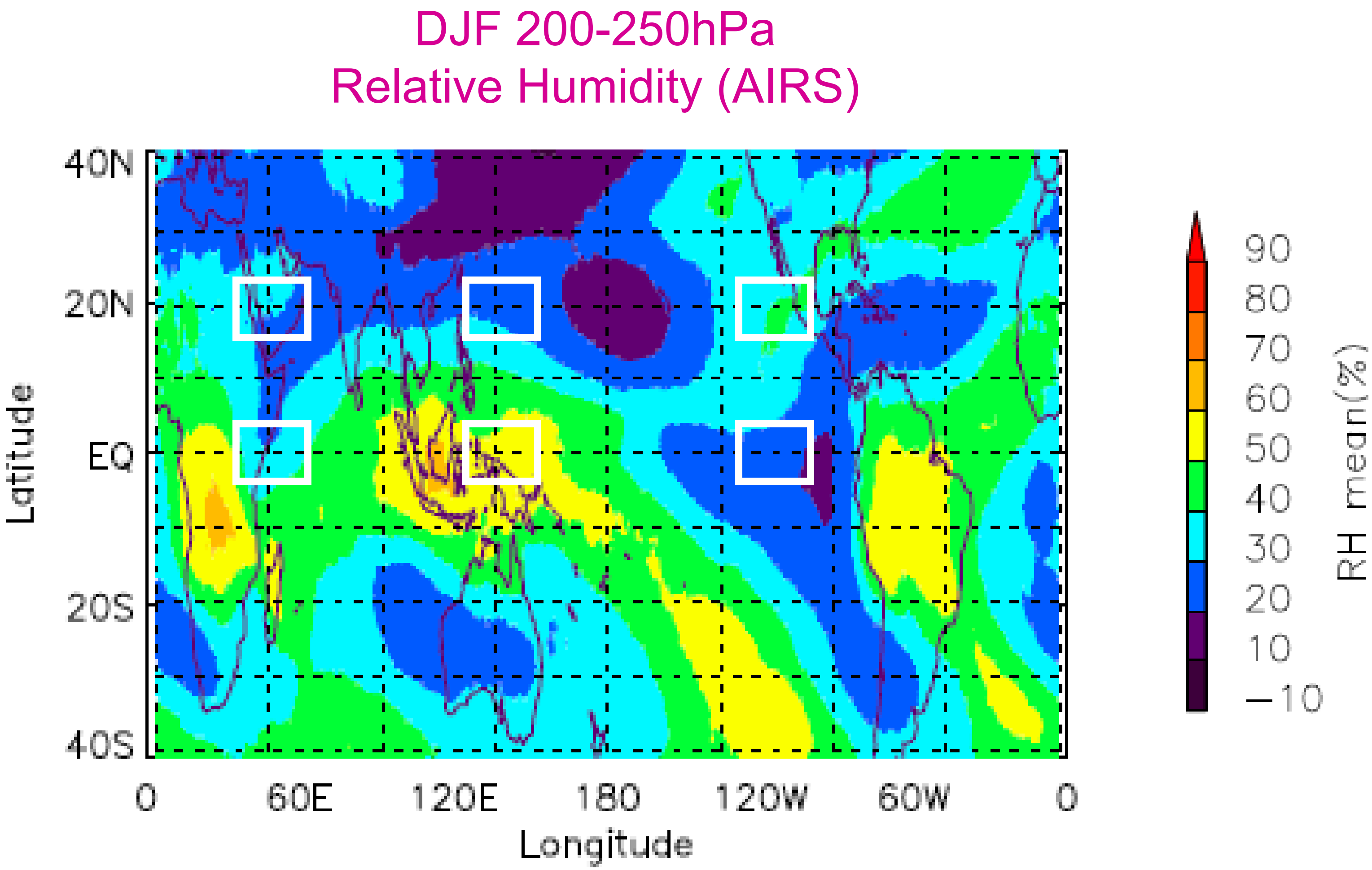
We examine the probability distribution functions (PDFs) of upper tropospheric relative humidity (RH) for measurements from

- Aura MLS
- Aqua AIRS
- UARS MLS

Consider spatial variations of PDFs. Focus here on DJF, ~215hPa

Also compare with theoretical distributions (generalization of Sherwood et al (2006) model).

Climatological UT Relative Humidity



- **Subtropics is drier than the Tropics**
- **But also significant zonal variations**

200-250hPa

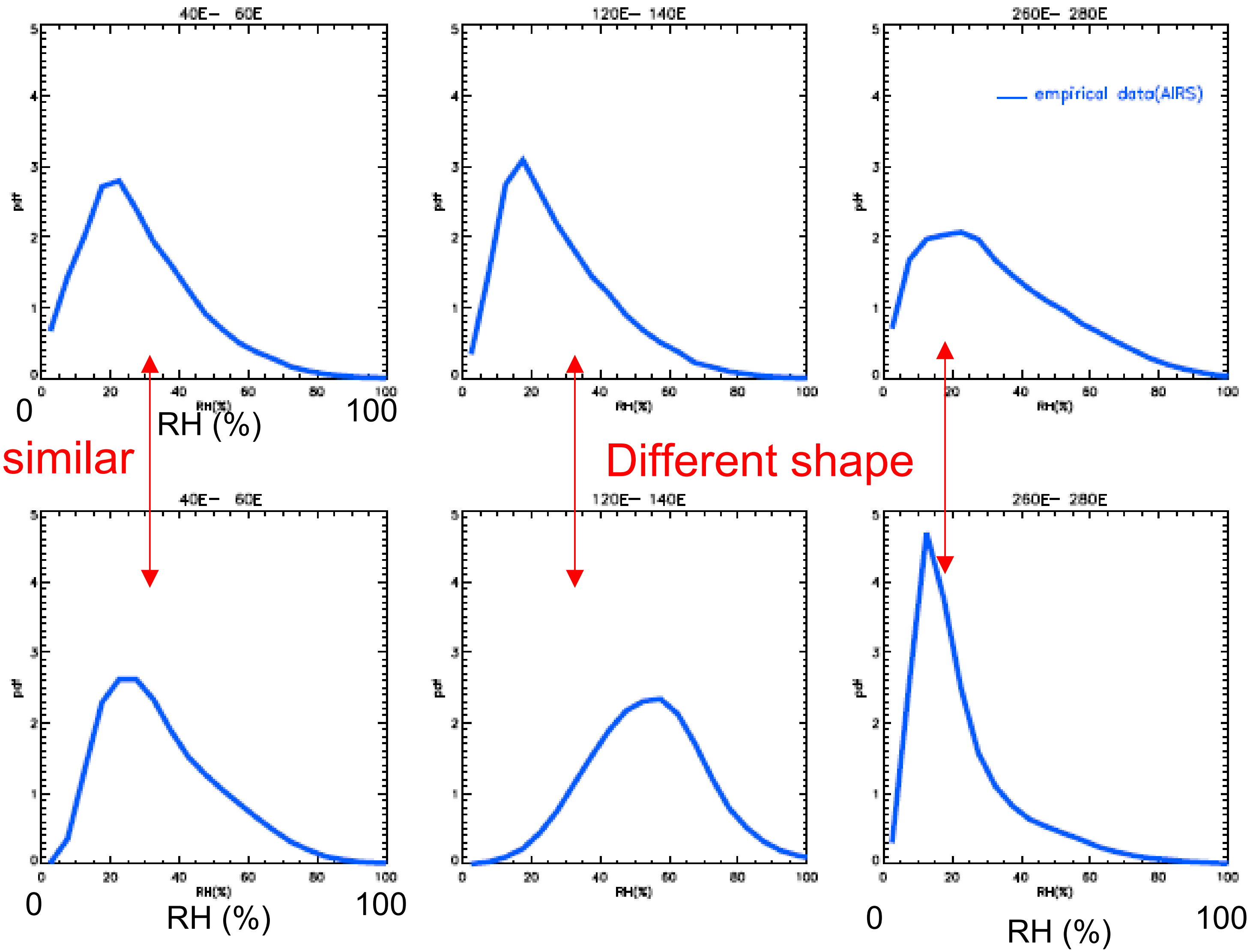
PDFs: AIRS

Large variation in PDFs - spread, skewness, …

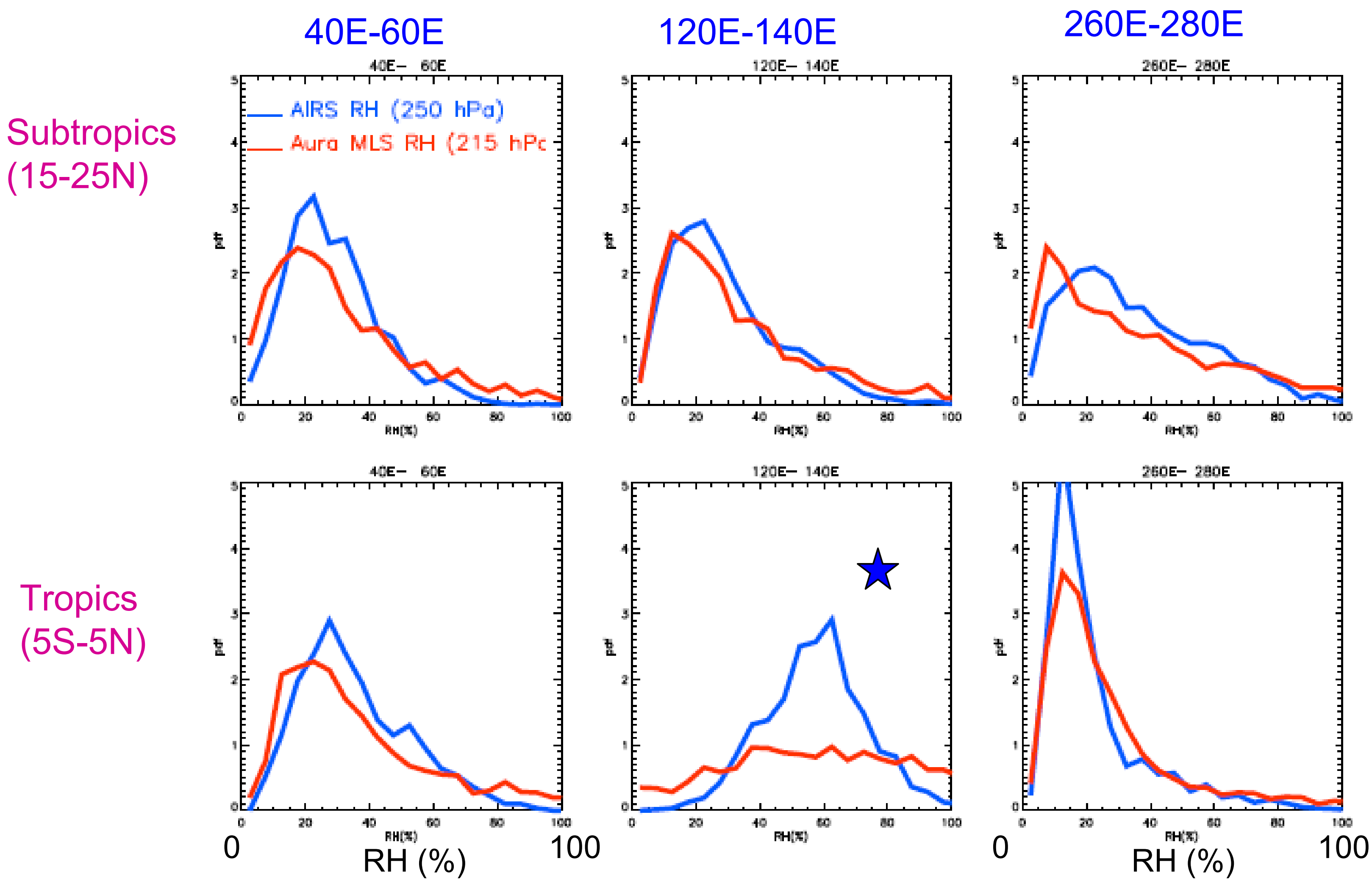
40E-60E | 120E-140E | 260E-280E

Subtropics (15-25N)

Tropics (5S-5N)



PDFS: AIRS - Aura MLS Comparison



Good agreement between AIRS and Aura MLS, with some exceptions.

Theoretical Model: Sherwood et al (2006)

Sherwood et al (J. Clim, 2006) showed that PDFs of Relative Humidity (R) in simple “advection-condensation” model are of the form:

$$\boxed{\mathrm{P}(R) = r\ R^{r-1}}$$

where

$r = \tau_{dry} / \tau_{moist}$,

τ_{dry} is drying time due to subsidence

[R~exp($-t/\tau_{dry}$)],

τ_{moist} is time scale of random remoistening events

[P(t) = exp($-t/\tau_{moist}$) / τ_{moist}], .

Larger r implies more rapid remoistening

Theoretical Model: Generalized Version

Generalized version of Sherwood et al model:

$$\boxed{\mathrm{P}\left(R\right) = \frac{k^k r^k R^{kr-1}}{\Gamma\left(k\right)}\left(-\log R\right)^{k-1}} \qquad r = \frac{\tau_{\mathrm{dry}}}{k\tau_{\mathrm{moist}}}$$

where time since last saturation is now modeled as

$$\mathrm{P}(t) = \frac{\exp\left(-t/\tau_{\mathrm{moist}}\right) t^{k-1}}{\tau_{\mathrm{moist}}^{k}\Gamma\left(k\right)}$$

k is measure of randomness of remoistening events.

k=1 is original Sherwood et al. model.

- Larger r implies more rapid remoistening
- Larger k implies less random remoistening processes.

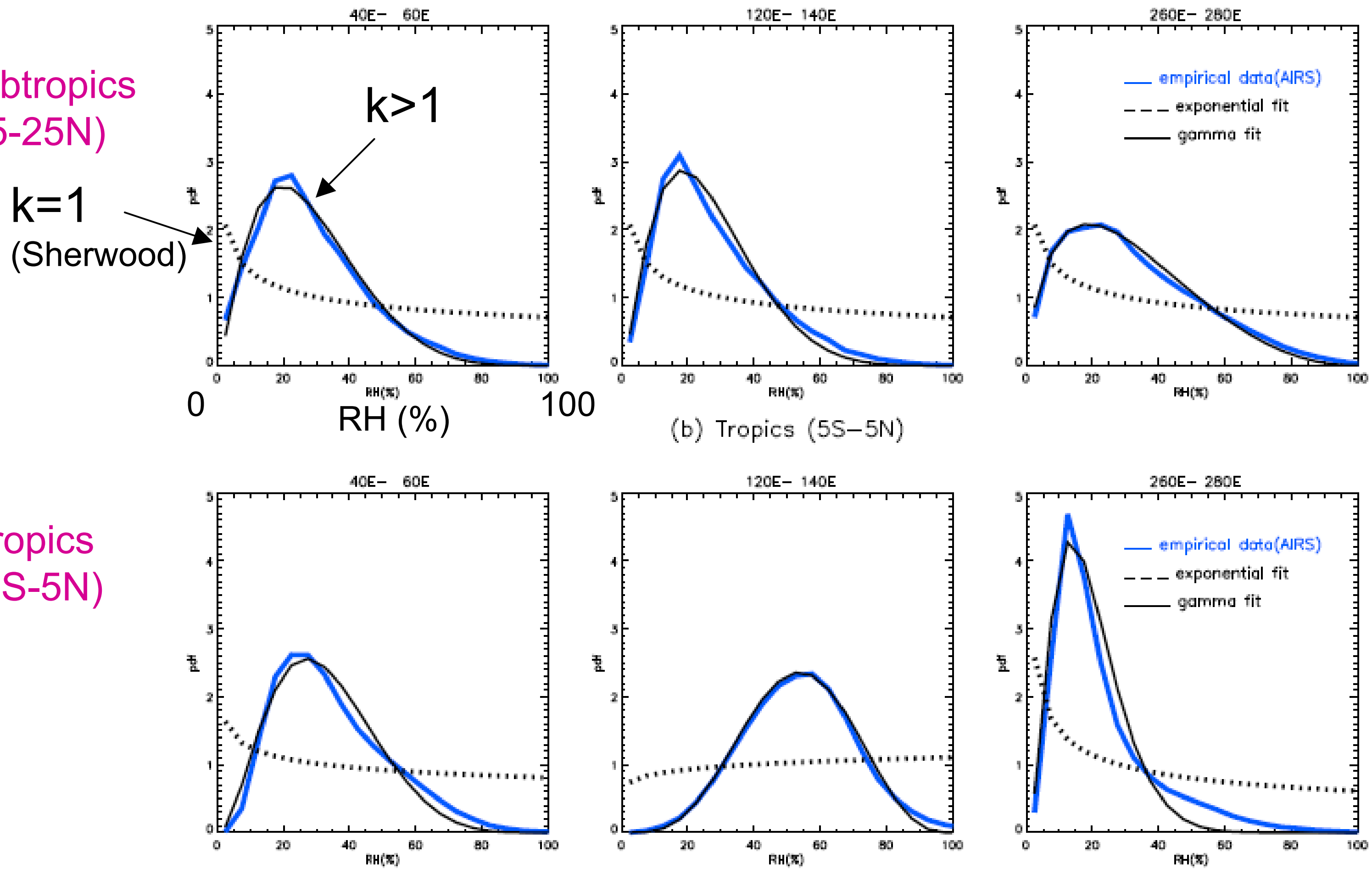
PDFs: Data and Model

How well do the theoretical models fit the observed PDFs?

40E-60E | 120E-140E | 260E-280E

Subtropics (15-25N)

Tropics (5S-5N)



Model can fit the observed PDFs, with r and k varying with location.

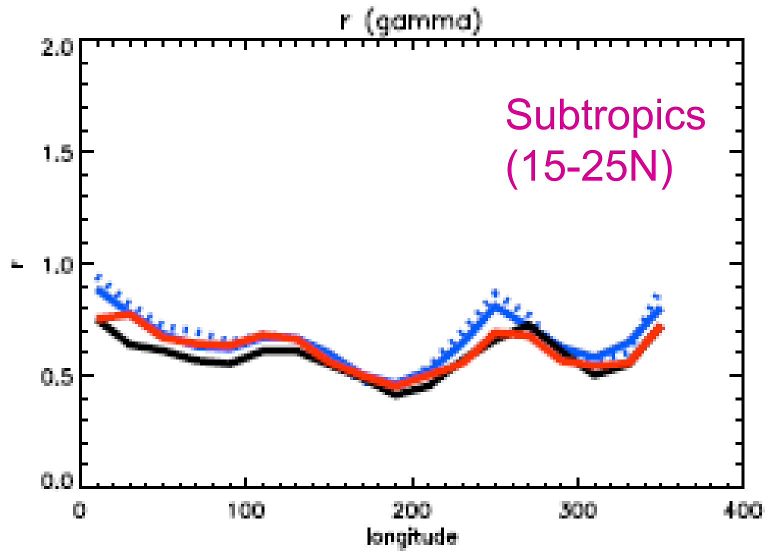
$r = \tau_{dry} / \tau_{moist}$

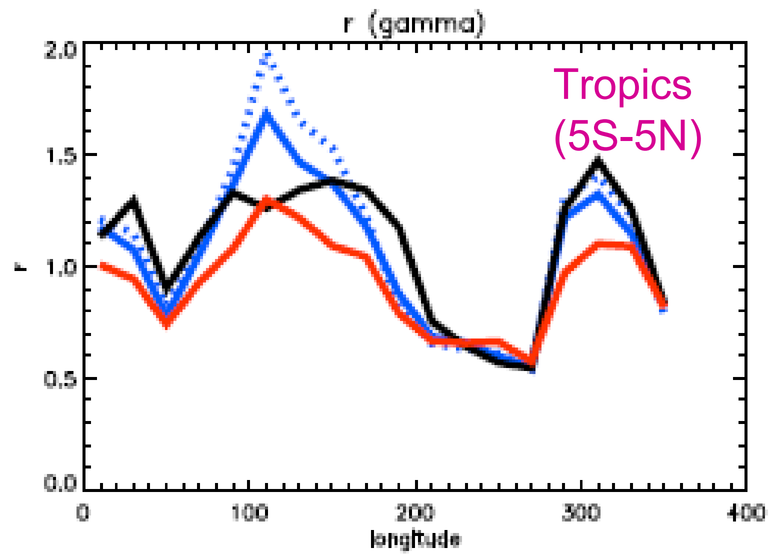
Spatial Variations in r

Good agreement between different data sets.

All show
r>1in tropical convective regions, and
r<1 in dry regions.

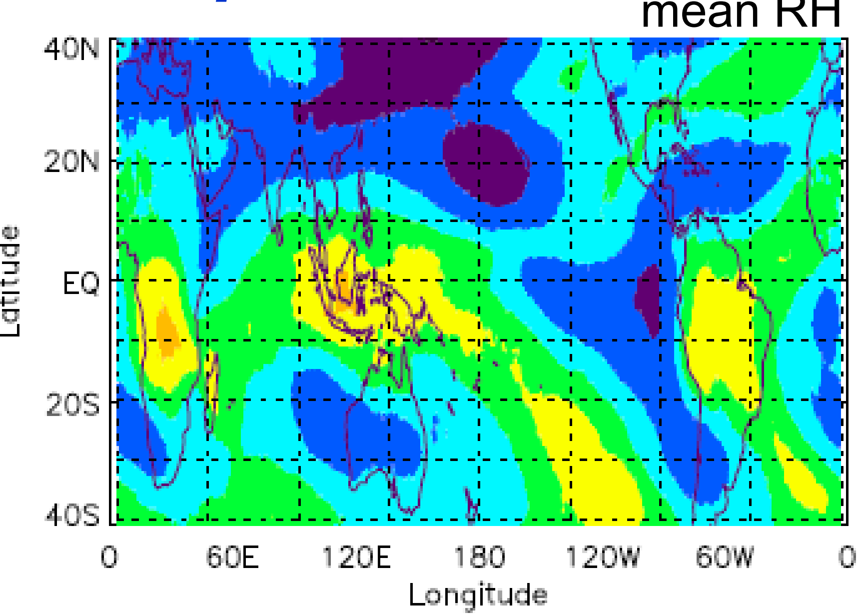
Expected as larger r implies more rapid remoistening

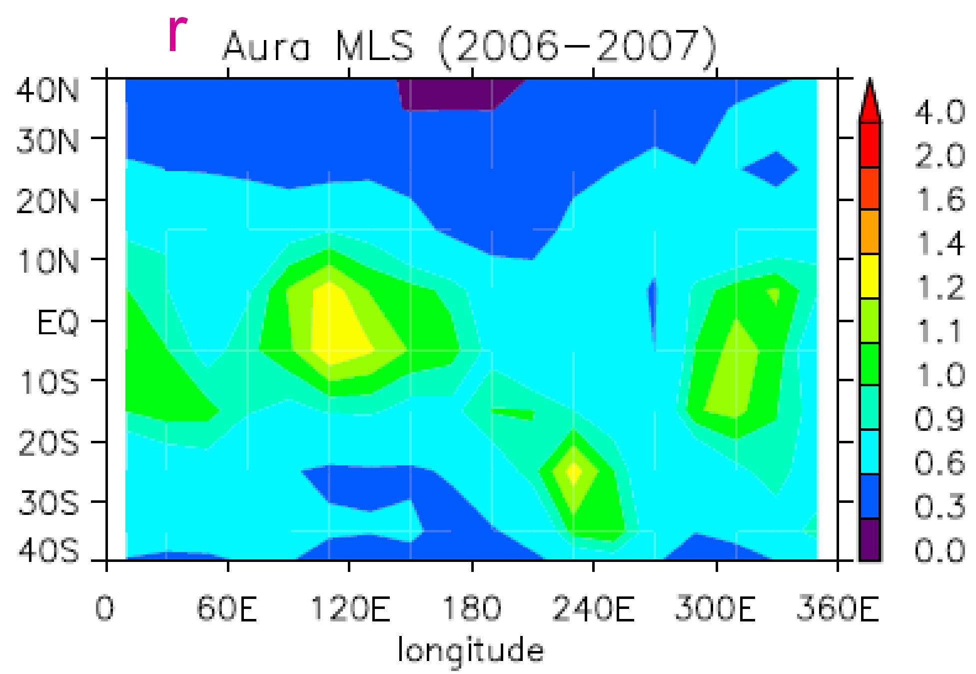


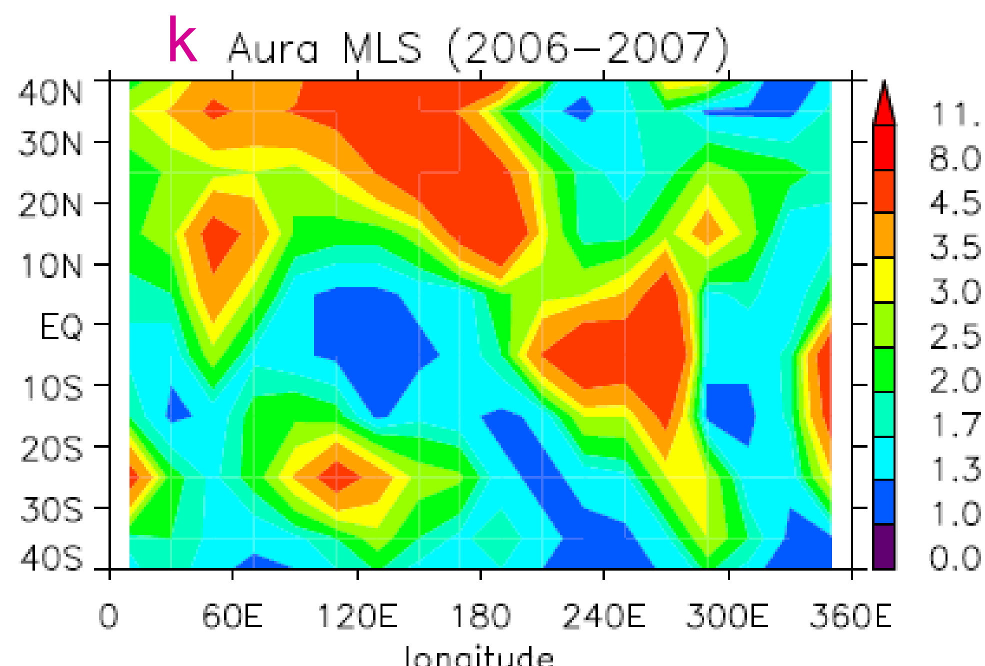


AIRS (2002–07)
AIRS (2005–07(match with MLS))
UARS MLS (1992–94)
Aura MLS (2005–07)

Maps of "r" and "k"







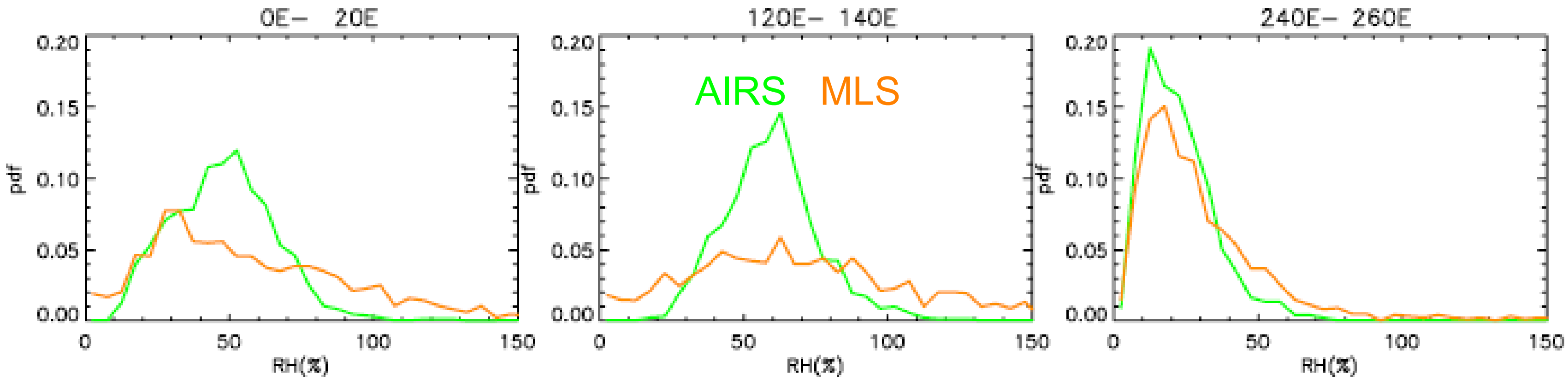
Convective Regions:

- r>1 and low k
- Rapid, random remoistening

Non-convective Regions:

- r<1 and high k
- Slower, more regular remoistening (horizontal transport)

Aura MLS - AIRS bias

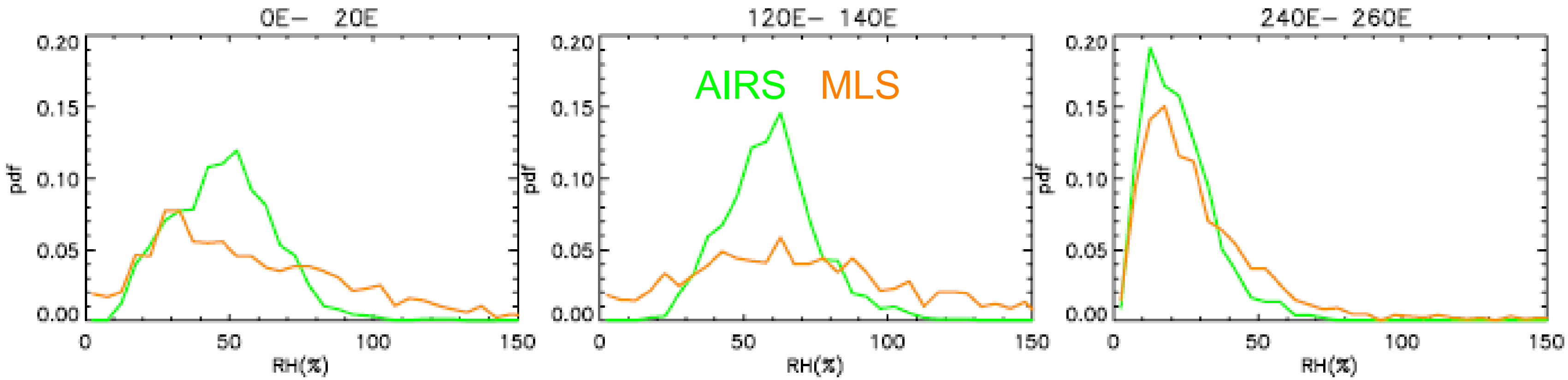


There are some differences between MLS and AIRS PDFs.

Differences are not simply a function of RH.

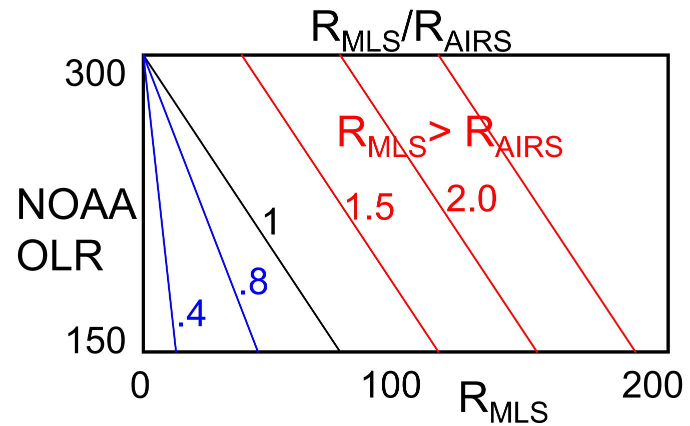
Is there a simple mapping between MLS and AIRS?

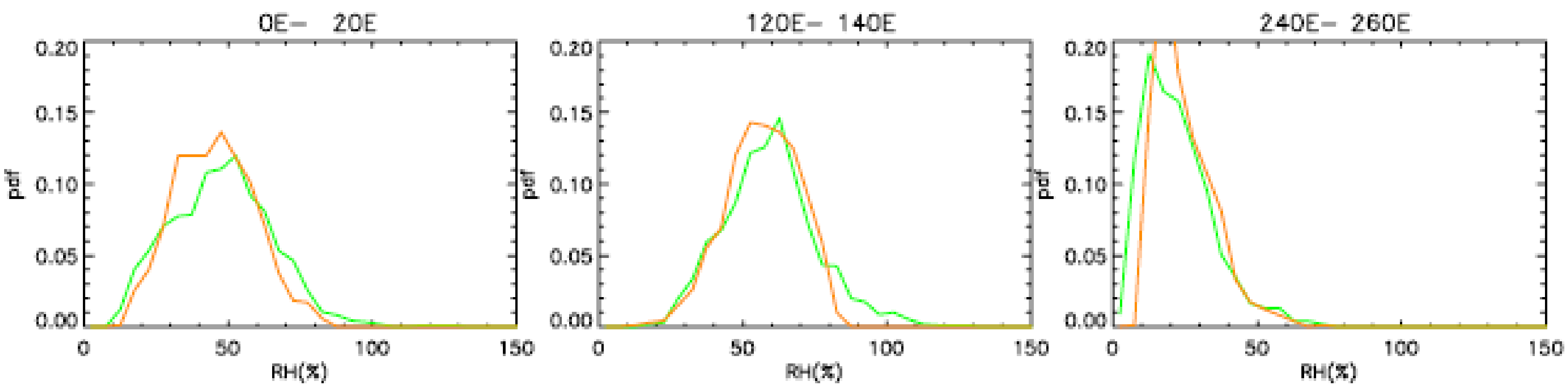
Aura MLS - AIRS bias



Transform MLS Data

$R_{MLS}/R_{AIRS} = f(R_{MLS}, OLR)$





Conclusions

Several robust features are found in the observed PDFs from all three data-sets (Aura and UAR MLS, AIRS):

• Well fit by a generalized version of the Sherwood et al. (2006) theoretical model.

• Consistent spatial variations in “r” (ratio of drying and moistening times) and “k” (randomness of moistening process).

• Variations in r and k can be related to variations in the physical processes controlling the RH distributions.

Differences between MLS and AIRS do exist. There is a rather simple mapping, which depends on OLR and RH, to account for bias between MLS and AIRS.